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INTRA-ORAL CAMERA SYSTEM WITH CHAIR-MOUNTED DISPLAY

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CROSS REFERENCE TO RELATED APPLICATIONS

This patent application is a continuation-in-part of commonly-assigned U.S. Patent Application Serial Number 10/238,174, which was filed on September 10, 2002, which is a continuation-in-part of commonly-assigned U.S. Patent Application Serial Number 09/796,239, which was filed on February 28, 2001.

FIELD OF THE INVENTION

The present invention relates to intra-oral imaging systems for dental applications, and particularly to an intra-oral camera system that is used by a dental practitioner to display images of objects in the mouth.

BACKGROUND OF THE INVENTION

Electronic handheld cameras configured with intra-oral imaging optics are used for capturing images of the inside of a patient's mouth. The camera typically has an elongated body that contains an image sensor and optics. The optics and sensor are designed for capturing images of the inside of the mouth when the distal or viewing end of the camera is inserted into the patient's mouth. Wires carrying electronic signals typically connect the image sensor to the proximal end of the camera where a communication interface is provided to an image processing system or display monitor that allows manipulation and display of the images. By viewing the displayed images, a diagnosis can be made and appropriate treatment prescribed.

For illuminating the inside of the mouth, a fiber optic cable typically is used to transmit light to the viewing end of the camera. The light is generated by a high intensity light source such as a lamp or bulb typically held in a light box. In a typical embodiment, such as shown in U.S. Patent No. 6,132,211, the fiber optic cable terminates in a connector that plugs into a power source housing that also includes the light source. Preferably, the housing for the power supply and the light source is supported on a countertop or on a post in the dental

operatory room. In other words, the housing is basically immovable and portability is provided by having the portable handpiece removable from the housing. According to the '211 patent, this design is chosen so that any number of operatories having a power source base and display may be serviced by a single handpiece system.

In a typical installation, the housing containing the power supply and the light box includes a communications interface to an external image processing system or display monitor. This leads to various placements of the processor and monitor. For instance, in the Reveal® Imaging Platform sold by Welch Allyn® the monitor is mounted on top of the housing, which makes the whole assembly virtually unmovable. Consequently, similar to what was described above in connection with the '211 patent, in the Reveal® Imaging Platform the handpiece is plugged into a receptacle on the housing.

The use of intra-oral cameras among dental practitioners is well known. Besides their use in the diagnosis of dental and oral disease, they are used as well in providing a visual record of the condition of the patient. It is frequently the case that a dentist, orthodontist, or the like, may have multiple operatories where the use of such a camera is desirable. Current camera systems require either the use of an attached computer system and video monitor, or a separate monitor for the display of images. Thus the practitioner is required to either purchase multiple camera systems or display capabilities for each operatory, as such display systems are rather large and bulky.

In many cases, a dentist desires to produce images of the interior of a patient's mouth in order to provide both a diagnosis of dental and oral disease as well as to provide a visual record of the condition of the patient. This process becomes cumbersome, costly, and inconvenient, as current camera systems are not designed for portability. What is needed is a truly portable camera system that would incorporate an integral display and provide advantages over the current state-of-the-art. Because of size and portability issues, were such a camera and display system to become available, it would be desirable to maximize ease of use

despite the small size and minimize the possibility of contamination due to dentist and patient interaction with the system.

SUMMARY OF THE INVENTION

The present invention is directed to overcoming one or more of the problems set forth above. Briefly summarized, according to one aspect of the present invention, the invention resides in a portable intra-oral capture and display system for use by a dental practitioner in connection with a patient seated in a dental chair. The system includes: a handpiece elongated for insertion into an oral cavity of the patient, said handpiece including a light emitter on a distal end thereof for illuminating an object in the cavity and an image sensor for capturing an image of the object and generating an image signal therefrom; a monitor interconnected with the handpiece, said monitor containing electronics for processing the image for display, and a display element for displaying the image, where the interconnection between the monitor and the handpiece includes an electrical connection for communicating the image signal from the image sensor in the camera to the electronics in the monitor; and a receptacle on the dental chair for receiving the monitor, wherein the receptacle conforms to the monitor such that the monitor may be withdrawn from the receptacle in order to allow the display element to be seen by the dental practitioner or the patient.

The advantage of the present invention lies in the integration of the display into a dental chair. This integration enables the practitioner to easily view and act upon the the results of image recording in close proximity to the capture location by interaction with the system, and conveniently display the captured image(s) either for the practitioner's or patient's benefit.

These and other aspects, objects, features and advantages of the present invention will be more clearly understood and appreciated from a review of the following detailed description of the preferred embodiments and appended claims, and by reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows an intra-oral camera and display system according to the invention.

FIG. 2 shows a block diagram of the electronics in the integral base.

FIG. 3 shows the integral base for the light source and hand held monitor of the system shown in Figure 1, particularly as it would be used for communication to a group of peripherals, including communication of color coordinates for an intra-oral object to an offsite dental facility for the fabrication of a prosthetic.

FIG. 4 shows a flow chart for a process for correcting the color of the system shown in Figure 1.

FIG. 5 shows a second embodiment of an intra-oral camera and display system according to the invention.

FIG. 6 shows a third embodiment of an intra-oral camera and display system according to the invention.

FIGS. 7A – 7D show a first embodiment of a contamination control device for use with the display system shown in Figure 1.

FIGS. 8A – 8C show a second embodiment of a contamination control device for use with the display system shown in Figure 1.

FIG. 9 shows a block diagram of the electronics in the integral base according to a further embodiment including a touch screen capability.

FIG. 10 shows a touch screen display for use with the intra-oral camera and display system shown in Figure 1.

FIG. 11 illustrates a standard dental chair and a portable monitor of the type shown in Figure 6 that is inserted into a receptacle under one of the armrests on the dental chair.

FIG. 12 illustrates how the portable monitor is removed from the receptacle under one of its armrests as shown in Figure 11.

FIG. 13 illustrates how the portable monitor shown in Figure 12 can be hinged to the receptacle and tilted upward for easy viewing.

FIG. 14 illustrates how the portable monitor is disconnected from the receptacle shown in Figure 11 and used as a wireless display.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Because intra-oral cameras employing electronic sensors are well known, the present description will be directed in particular to elements forming part of, or cooperating more directly with, apparatus in accordance with the present invention. Elements not specifically shown or described herein may be selected from those known in the art. Certain aspects of the embodiments to be described may be provided in software. Given the system as shown and described according to the invention in the following materials, software not specifically shown, described or suggested herein that is useful for implementation of the invention is conventional and within the ordinary skill in such arts.

Referring first to Figure 1, an intra-oral dental camera system 10 includes a portable dental camera 12 and a power source, illumination source and a display unit integrally located in a portable enclosure (hereinafter referred to as the integral base 14) tethered to the camera 12. The camera 12 and the integral base 14 thus constitute, in the terms of this invention, an intra-oral camera with integral display. The dental camera 12 includes a handpiece 16 and a cable 18 connecting the dental camera 12 to the integral base 14. As shown for illustrative purposes in Figure 1, the integral base 14 can be easily cradled in a hand, and includes a display monitor 20 that can be easily hand positioned relative to the dentist's and/or patient's line of sight. A set of user controls 22 are provided on the integral base 14 that can be easily hand-navigated for controlling the illumination and the images displayed on the monitor, as well as communicating with peripheral devices. The handpiece 16 supports a removable lens unit 24 that includes a lens 26 and light emitting apertures 28. The handpiece 16 is generally elongated and cylindrical with a central axis. The lens 26 is positioned to receive

light impinging on the handpiece in a direction substantially perpendicular and normal to the central axis of the handpiece.

Referring to Figure 2, the integral base 14 further includes a central processing unit (CPU) 30, a CPU memory 31, a power supply 32, a wireless transceiver 34, and flash memory (RAM) 36. The user controls 22 interface with a video control unit 38 and an illuminator control unit 40. The illuminator control unit 40 connects with an illumination source 42, which provides illumination to the handpiece 16 through a fiber optic 44 that is part of the cable 18. The illumination source may take a variety of forms known to those of skill in this art, such as a halogen arc lamp lighting system or a tungsten/halogen lamp. The power supply 32 is connected by a power cable (not shown) to a power source, such as a wall socket. The image signal communication between the handpiece 16 and the CPU 30 is maintained through an electrical connection 46, which is also in the cable 18. While not shown in detail, the handpiece 16 also supports a connection of the fiber optic 44 with the light emitting apertures 28 and a connection of the electrical conductor 46 to an image sensor 50, such as a conventional charge coupled device (CCD). The image sensor 50 is arranged in a conventional optical path, with mirrors and other optical components as might be necessary, such that the lens 26 can form an image of an intra-oral object on the image sensor 50.

It should be noted that portability is facilitated by incorporating into the dental camera system 10 both a high quality image display 20 along with means to transfer image data to a physically separate and distinct data storage associated with an image printing capability. The high quality image display may be provided by a number of well-known technologies; for example, it is well-known in the art of hand-held televisions (e.g., the Casio EV660 Color Active Matrix Handheld TV) to use a small (e.g., 3 inch) screen with thin-film transistor active matrix (TFT) technology. The means to accommodate a transfer of image data may include (a) wireless RF or microwave transceiver technology, (b) wireless infra-red transmission technology, and/or (c) removable memory technology embodied in physically small elements, such as flash RAM cards or

small hard drives, that are easily removed from the camera part of the system and subsequently plugged into either the image data storage or printer parts of the system.

Accordingly, the dental camera system 10 can, through the transceiver 34 in its integral base 14, initiate communication via wireless links 58 with a variety of peripheral units as shown in Figure 3. Each of these units would have its own data storage for receiving the transmitted images. Without intending to be exhaustive as to type of peripheral unit that may be accessed, such peripheral units include a larger monitor or television receiver 60, a printer 62, and a computer system 64, such as any conventional desktop PC, where the images may be stored. With this arrangement, a dental practitioner may view an image on the integral base 14 and immediately initiate its transfer to any one of the peripheral units 60, 62 or 64 by means of the user controls 22. The incorporation of the transceiver 34 and the display monitor 20 into the dental camera system 10 further enables the practitioner to view the results of an image recording, and conveniently display the captured image(s) either for the practitioner's or patient's benefit. For this purpose, the transceiver 34 would receive images from a storage peripheral, such as the computer system 64, and display the stored images on the display monitor 20. Importantly, such viewing occurs without the requirement of producing a physical print of the image.

Just as importantly, with this arrangement the practitioner can separate the movable, but clumsy and sometimes bulky, printing and processing operation from the dental operatory, and devote a particular room to these peripherals. Moreover, incorporation of the display as a tethered adjunct to the camera system removes the requirement on the dentist to move a large bulky system (a video monitor and/or attached computer) from one operating room to the next. Alternatively, the requirement that the dentist purchase multiple such systems for multiple operatories is eliminated.

In a preferred embodiment, the image sensor 50 provides an image signal that the CPU 30 processes (as a video signal) for display on the display monitor 20. The video control unit 38 interacts through the CPU 30 and the user

controls 22 to provide functionality for several modes, including a video/still mode, a mode for initiating a recording of a still or video sequence, a mode for stopping the imagery at any point (freeze-frame), a mode for initiating transmission to any of the peripherals shown in Figure 3 and a mode for initiating retrieval of a stored image from an external memory, e.g., from the computer system 64. In the latter two modes, the images are transmitted and/or received via an antenna or light beam emitter (not shown) to/from any of the peripherals 60, 62 or 64. Alternatively, the images may be stored in a removable memory and the removable memory is then transported to the peripheral units. For instance, the integral base 14 may also include a receptacle 66 for a physically small RAM card 68, which may be easily removed from the integral base 14 and subsequently plugged into a corresponding receptacle (not shown) in any one of the peripheral units 60, 62 and 64.

In order to adjust the colorimetry of the dental camera system 10 to match the color of intra-oral objects, e.g., to match a natural tooth color, it is desirable to provide an optimum color calibration for an intra-oral camera application. Figure 4 shows the process for correcting the color of a system designed for the collection of intra-oral images. It is desirable to have a broadband match (broadband spectrum) because of the need to match teeth under a variety of illumination conditions. The camera is first initialized in a stage 70 to clear previous color correction factors from the CPU memory 31. These can be in the form of look up table elements, matrix elements, and the like. As is well-known in the color management arts, these digital data are used in a mathematical transformation process to modify the color characteristics of components of the system to allow for a true color rendition to occur throughout the system. The illuminator is allowed to stabilize for a period of time so that the spectral output of the illumination source 42 remains the same for a period of time that allows multiple images to be captured, without the need for adjustment of the illuminator color temperature (or spectral output characteristics). The display monitor 20 may also require a period of stabilization before use.

In stage 72, target materials are illuminated with the illumination source 42 so as to characterize the image recording response. Such target materials can include, but are not limited to, color matching charts for the fabrication of color-matched prostheses. For example, the target materials would include the white(s) that dental practitioners use to match teeth for prosthetic purposes, such as the fabrication of a crown. (Note that calibration would ordinarily not be done with the intra-oral camera in a patient's mouth; the camera would typically be hooked up to the computer 64 for this calibration process.) Calibration of the system includes measurements of such targets to establish the characteristic input color response for the intra-oral camera system. The characteristic is stored digitally in stage 74 in the CPU memory 31 and used to transform the unknown color of the teeth (which are imaged in a separate image recording event or events resulting from stage 76) to a color representation within the system that can be used to produce a "true-color" output. The calibration of each output device is also performed and stored in stage 78 in the respective memories (not shown) of each output device. Then, the dental image is output to a selected output device(s) in stage 80, e.g., to the display monitor 20 or any of the output devices 60, 62 and 64 shown in Figure 3. In this manner, the system can correct for color imbalance in any of the components in the system and render color corrected output regardless of the output channel.

In addition to the many output channels considered in Figure 3, and the transmission of a color corrected image to an output device, transmission of data describing the color of a tooth or teeth is valuable. Using a color corrected system such as described above would enable a practitioner to accurately determine the color of a patient's teeth with the purpose of replicating the color in a prosthesis. Thus the practitioner could "shade match" a crown or other prosthetic device to the tooth to be replaced or other teeth proximate to the replaced tooth. Color matching calculations can be performed in CPU memory 31 and the results of such a calculation, the color coordinates of the tooth in question, can be transmitted over a computer network, e.g. the Internet, connected to the computer system 64 shown in Figure 3, or via other means, e.g., disk or tape, to a

lab technician in an offsite location, such as a dental laboratory facility 65 as shown in Figure 3, where an appropriate prosthetic device would be fabricated. (Alternatively, under certain situations the prosthetic device may be fabricated in the dental operatory or elsewhere in the dentist's own facility.)

In a second embodiment of the intra-oral camera and display system shown in Figure 5, the system includes a docking unit 100 with a recessed area 102 for mating with the integral base 14. The power supply 32 in the integral base 14 includes rechargeable batteries 104 connected to externally accessible charging electrodes 106. The docking unit 100 is provided with a battery charger 108 connected to externally accessible charging electrodes 110. When the integral base 14 is inserted into the recessed area 102 on the docking unit 100, the electrodes 106 and 110 are electrically connected and the batteries 104 are recharged.

In a third embodiment of the intra-oral camera and display system shown in Figure 6, the handpiece 16 of the system includes electronics and an interface for communicating with the integral base 14 across a wireless transmission linkage 116 or by means of a removable memory 118. More specifically, the handpiece 16 includes its own light source 120, processor 122, transceiver 124 and power supply 126. In addition, the power supply 126 may include rechargeable batteries 128, and the intra-oral camera and display system can further include a docking unit 130 with a battery charger 132. Both the handpiece 16 and the docking unit include mating electrodes 134 and 136 such that when the handpiece 16 is inserted into the docking unit 130, the electrodes 134 and 136 are electrically connected and the batteries 128 are recharged. In addition, as shown in Figure 5, the integral base may have its own docking unit; moreover, the two docking units could be combined in one component.

Because of the liklihood of contamination due to contagious afflictions that can be passed on to patients and staff when the same device is used with more than one patient, a contamination control device may be added to the intra-oral capture and display system. In an embodiment of the invention shown in Figures 7A – 7D, the contamination control device is a clear sleeve or pouch

200 having a flap 202 lined with an adhesive 204. One side of the pouch 200 has a slot 206, as shown in a top view in Figure 7A, which provides clearance for the cable 18 (of course, if the connection with the camera is a wireless connection, then the slot 206 is unnecessary and may be omitted). As shown by the arrow 208 in Figure 7B, the integral base 14 slides into the pouch 200 and the flap 202, as shown in a top view in Figure 7C, is closed; the pouch is than used with a single patient and then disposed after the patient's visit. In a front view, as shown in Figure 7D, the display monitor 20 is visible through the transparent front panel 210 of the pouch 200.

Figures 8A – 8C show an alternate embodiment of the pouch 200 including multiple clear layers 212 attached to the front of the pouch 200 by a plurality of tear off tabs 214. As shown by the arrow 208 in Figure 8A, the integral base 14 slides into the pouch 200 and the flap 202, as shown in a top view in Figure 8B, is closed. In a front view, as shown in Figure 8C, the display monitor 20 is visible through the transparent multiple clear layers 212 on the front of the pouch 200. In use, as shown in the top view in Figure 8B, the top layer 216 of the multiple clear layers 212 can be peeled off at the tear off tabs 214 and thrown away, revealing a clean, sterile layer for the next patient.

Figure 9 shows the block diagram of the electronics in an integral base that includes a touch screen capability according to the invention. Most of the electronics in Figure 9 is the same as shown in Figure 2, and common electronic components sharing the same reference characters as in Figure 2 will not be further described unless they relate in particular to the touch screen capability. A touch screen is a type of display screen that has a clear touch sensitive transparent panel 21 covering the screen of the monitor 20. Instead of using a pointing device such as a mouse or a light pen, a finger may be used to point directly at objects (touch screen controls 23) on the screen of the display monitor 20. The touch sensitive panel 21 may be sized to fit over substantially the entire display screen 20 or it may fit over a limited area 21' (see Figure 10) of the display screen where it is desirable to locate a set of touch sensitive controls. The touch sensitive panel 21 registers touch events and passes these signals to a touch

screen controller 33, which then processes these signals and sends them to the CPU 30. The CPU 30 includes driver software (stored in memory 31) for telling the CPU 30 how to interpret the touch event information that is sent to the controller 33. The driver software allows the CPU 30 to reconfigure the touch screen controls 23 to represent different sets of control events. For purposes of this disclosure, the touch screen controller 33 and its related driver software will be referred to as the touch screen interface

As shown in Figure 10, the touch sensitive panel 21 (or 21') may be configured to display a specific group of controls, including a zoom in touch control 220, a zoom out touch control 221, a pan up touch control 222, a pan down touch control 223, a pan right touch control 224, a pan left touch control 225 and a save touch control 226 (thereby allowing the user to save the current image). Furthermore, the control buttons 22 may be employed in conjunction with the video control unit 38 to scroll through other control configurations that may be produced by the touch screen interface and displayed on the touch sensitive panel 21 (or 21'). For instance, the touch screen interface may allow the user to initiate transfer of the image to a peripheral device across the output interface, or to retrieve an image from the peripheral device across the output interface.

The specific controls shown in Figure 10 are intended as a suggestion for a preferred set, but are not intended as a limitation; any number and type of controls may be selected and displayed depending on the application. Moreover, many of the functions needed on a display of this type are dependent on the image being displayed. For instance, different controls may be appropriate depending on whether video or still, or single or multiple, images are being displayed (which are all possible display capabilities of an intra-oral camera). Consequently, typical functions that might be rendered on a touch sensitive panel include:

- Zoom (plus and minus)
- Pan (left, right, up, down)
- Image select

- Where to zoom (touching display image itself versus a screen button)
- Save image
- Add image to patient record
- Change exposure
- Enhancements
- Color modifications
- Analyses

In a further embodiment of the invention shown in Figures 11 - 14, the handpiece of the intra-oral camera and display system includes electronics and an interface for electrically interconnecting the image signal from the handpiece to the integral base across an electrical linkage, which for example may be a hardwired linkage, an optical linkage, a wireless transmission linkage or any other suitable form of transmission linkage. More specifically, and as shown in connection with Figure 6, the handpiece 16 would ordinarily include its own light source 120, processor 122, transceiver 124 and power supply 126. The integral base 14, for purposes of this further embodiment, is a small monitor 302 including a small display element 303 (shown best in Figure 12). More specifically, Figure 11 illustrates the further embodiment in use with a standard dental chair 300, where a small monitor 302 of the type shown in Figure 6 is inserted into a receptacle 304 mounted under one of the armrests 306 on the dental chair 300. The receptacle 304 conforms to the shape of the monitor 302 such that the monitor 302 may be withdrawn from the receptacle 304 in order to allow the display element 303 to be seen by the dental practitioner or the patient. For instance, Figure 12 illustrates how the monitor 302 is removed from the receptacle 304 under one of its armrests 306. As shown in Figure 13, the monitor 302 shown in Figure 12 can be hinged to the receptacle 304 via a hinge connection 308 and tilted upward for easy viewing. As was shown in Figure 6, the integral base 14 may be electrically interconnected with the handpiece via a wireless connection 116. Accordingly, Figure 14 illustrates how the monitor 302 is disconnected from the its receptacle 304 and used as a small, portable wireless display.

Although preferably mounted under an armrest 306, it should be understood that the receptacle 304 may be mounted to other parts of the dental chair, such as along the leg rest portion or the head rest portion. Indeed, the receptacle may be associated with some other nearby piece of dental apparatus, such as a light fixture. Moreover, the notion of a "receptacle" is merely intended to describe a structural or supporting feature that conforms sufficiently to the monitor 302 so as to support the monitor 302 when it is inserted into the feature and to enable easy withdrawal of the monitor 302 from the feature. Accordingly, this may be without limitation a substantially enclosed space such as a pocket, or a relatively open space such as a framework. The specific material used for the receptacle is unimportant as long as it performs its supporting function, i.e. it may vary from a relatively soft pocket to a firm framework.

Furthermore, the monitor 302 shown in Figures 11 – 14 may include the contamination control devices shown in Figures 7A – 7D or Figures 8A – 8C. The touch screen capability shown in Figures 9 and 10 may also be incorporated in the monitor 302.

The invention has been described with reference to a preferred embodiment. However, it will be appreciated that variations and modifications can be effected by a person of ordinary skill in the art without departing from the scope of the invention.

PARTS LIST

10 dental camera system
12 portable dental camera
14 integral base
16 handpiece
18 cable
20 display monitor
21 touch sensitive panel
21' limited area
22 user controls
24 removable lens unit
26 lens
28 light emitting apertures
30 CPU
31 CPU memory
32 power supply
33 touch screen controller
34 wireless transceiver
36 flash memory
38 video control unit
40 illuminator control unit
42 illumination source
44 fiber optic
46 electrical conductor
50 image sensor
58 wireless link
60 larger monitor or television receiver
62 printer
64 computer system
65 dental laboratory facility
66 receptacle

68 RAM card
70 initialize stage
72 illuminate target stage
74 compute stage
76 record stage
78 output compute stage
80 output select stage
100 docking unit
102 recessed area
104 rechargeable batteries
106 charging electrodes
108 battery charger
110 charging electrodes
116 wireless link
118 removable memory card
120 light source
122 processor
124 transceiver
126 power supply
128 rechargeable batteries
130 docking unit
132 battery charger
134 electrodes
136 electrodes
200 pouch
202 flap
204 adhesive
206 slot
208 arrow
210 transparent front panel
212 multiple clear layers

214 tear off tabs
220 zoom in touch control
221 zoom out touch control
222 pan up touch control
223 pan down touch control
224 pan right touch control
225 pan left touch control
226 save touch control
300 standard dental chair
302 small monitor
303 small display element
304 receptacle
306 armrest
308 hinge